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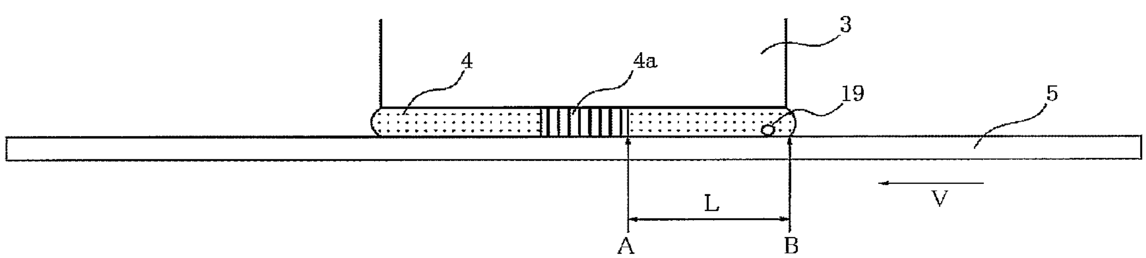
**(54) Title:** EXPOSURE APPARATUS AND DEVICE MANUFACTURING METHOD




**(57) Abstract:** An exposure apparatus includes a projection optical system 3 for projecting a pattern on a mask 3 onto a substrate 5, a stage 13 for retaining and moving the substrate, and liquid film forming means (10, 11) for forming a liquid film 4 between a final surface of the projection optical system and the substrate, wherein L / V > fÑ is met where fÑ is a life of a gas bubble generated in the liquid film, V is a moving speed of the substrate, and L is a distance from an interface of the liquid film to an exposure area along a moving direction of the substrate.

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# DESCRIPTION

# EXPOSURE APPARATUS AND DEVICE MANUFACTURING METHOD

## TECHNICAL FIELD

This invention relates generally to an exposure apparatus that utilizes an immersion method, and is suitable, for example, for the lithography process for manufacturing highly integrated devices, such as semiconductor devices, *e.g.*, ICs and LSIs, image pick-up devices, *e.g.*, CCDs, display devices, *e.g.*, a liquid crystal panels, communication devices, e.g., optical waveguides, and magnetic heads by transferring a pattern on a mask (or a reticle) onto a photosensitive agent applied substrate.

## BACKGROUND ART

An exposure apparatus for exposing a mask pattern onto a photosensitive-agent applied substrate have conventionally been used to manufacture semiconductor devices and liquid crystal panels. Since finer processing of a pattern is demanded for improved integrations of devices, exposure apparatuses are improved so as to resolve fine patterns.

The following Rayleigh equation (1) defines resolution R of a projection optical system in an exposure apparatus, which is an index of a size of a resolvable pattern:

$$R = k_1 (\lambda / NA) \qquad (1)$$

where $\lambda$ is an exposure wavelength, NA is a numerical aperture of the projection optical system at its image side, and $k_1$ is a constant determined by a development process and others, which usually is approximately 0.5.

As understood from Equation (1), the resolving power of the optical system in the exposure apparatus becomes higher as the exposure wavelength is shorter and the image-side NA of the projection optical system is greater.

Therefore, following the mercury lamp i-line (with approximately 365 nm in wavelength), a KrF excimer laser (with approximately 248 nm in wavelength) and an ArF excimer laser (with approximately 193 nm in wavelength) have been developed, and more recently an $F_2$ excimer laser (with approximately 157 nm in wavelength) is reduced to practice. However, a selection of the exposure light having a shorter wavelength makes it difficult to meet material requirements with respect to transmittance, uniformity and durability, etc., causing an increasing cost of the apparatus.

An exposure apparatus having a projection optical system with a NA of 0.85 is commercially available, and a projection optical system with a NA of 0.9 or greater is researched and developed. Such a high-NA exposure apparatus has difficulties in maintaining good imaging performance with little aberration over a large area, and thus utilizes a scanning exposure system that synchronizes the mask with a substrate during exposure.

However, a conventional design cannot make the NA greater than 1 in principle due to a gas layer having a refractive index of about 1 between the projection optical system and the substrate.

On the other hand, an immersion method is proposed as means for improving the resolving power by equivalently shortening the exposure wavelength. It is a method used for the projection exposure, which fills liquid in a space between the final surface of the projection optical system and the substrate, instead of filling this space with air as in the prior art.

The immersion method has an advantage in that the equivalent exposure wavelength has a wavelength of a light source times 1 / n, where n is a refractive index of the used liquid. This means that the resolving power enhances by 1 / n times the conventional resolving power, even when the light source having the same wavelength is used.

For example, when the light source has a wavelength of 193 nm and the liquid is water, the refractive index is about 1.44. Therefore, use of the immersion method can improve the resolving power by 1 / 1.44 times the conventional method.

In general, there are proposed two methods for filling liquid between the final surface of the projection optical system and the substrate for the exposure apparatus that utilizes the immersion method. One method puts the final surface of the projection optical system and the substrate under the water in a sink (see, for example, Japanese Patent Application, Publication No. 6-124873). The other is a local fill method that flows liquid in a space between the projection optical system and the substrate and creates a liquid film (see, for example, Japanese Patent Application, Publication No. 63-49893 and International Publication WO99/49504).

In the above two methods, the first method that puts the final surface of the projection optical system and the substrate under the water in a sink, disadvantageously makes the apparatus larger. On the other hand, a problem of the local fill method is influence of light scattering due to gas bubbles. The local fill method generates gas bubbles due to the atmosphere entrapped as the substrate moves. In general, an area of an exposable region at one time is

much smaller than that of the substrate in the manufacturing process of devices, such as a semiconductor and a liquid crystal panel. Therefore, it is necessary to move the substrate at a high speed during exposure. The local fill method inevitably generates gas bubbles as a result of that the atmosphere is confined in a concave / convex pattern on a substrate surface when a predetermined portion of the substrate moves beyond the gas-liquid interface at the end of the liquid film. Since the size of the gas bubble in this case has an order of 1 μm, the viscous force restricts actions and it is difficult to eliminate the gas bubbles. In the exposure apparatus of the conventional local fill system, as disclosed in an embodiment in International Publication WO99/49504, a range of the liquid film is made a little larger than the exposure area but its range is made as small as possible. Therefore, the gas bubbles are generated and enter the exposure area as soon as the substrate moves beyond the gas-liquid interface at the end of the liquid film. These gas bubbles that enter the exposure area scatter the exposure light, and varies the transferred pattern's critical dimension beyond the permissible range, causing insulations and short circuits contrary to the design intent in the worst case.

Accordingly, an exposure apparatus is demanded which utilizes an immersion method of a local fill system that can prevent entries of gas bubbles into the exposure area.

## DISCLOSURE OF THE INVENTION

An exposure apparatus according to one aspect of the present invention includes a projection optical system for projecting a pattern on a mask onto a substrate, a stage for retaining and moving the substrate, and a liquid film forming means for forming a liquid film between a final surface of the projection optical system and the substrate, wherein $L / V > \tau$ is met where $\tau$ is a life of a gas bubble generated in the liquid film, V is a moving speed of the substrate, and L is a distance from an interface of the liquid film to an exposure area along a moving direction of the substrate.

A scanning exposure apparatus according to another aspect of the present invention includes a projection optical system for projecting a pattern on a mask onto a substrate, a stage for retaining and moving the substrate, and a liquid film forming means for forming a liquid film between a final surface of the projection optical system and the substrate, wherein a distance is between 10 mm and 100 mm from an interface of the

liquid film to an exposure area along a moving direction of the substrate, and a distance is between 5 mm and 80 mm from an interface of the liquid film to an exposure area along a moving direction orthogonal to a scan direction of the substrate.

Other feature and advantages of the present invention will be apparent from the following description taken in conjunction with the accompanying drawings, in which like reference characteristics designate the same or similar parts throughout the figures thereof.

**BRIEF DESCRIPTION OF DRAWINGS**

The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate embodiments of the invention and, together with the description, serve to explain the principles of the invention:

FIG. 1 is a schematic view of principal part of an exposure apparatus according to a first embodiment.

FIG. 2 is a view of a liquid film part in the apparatus shown in FIG. 1.

FIG. 3 is a view showing a relationship between a life $\tau$ of a gas bubble and a diameter $d_0$ of the gas bubble.

FIG. 4 is a view showing a relationship between a liquid film forming range and an exposure area.

FIG. 5 is a view showing a relationship between a normalized life of a gas bubble and a normalized concentration of dissolved gas.

FIG. 6 is a schematic view of a principal part of an exposure apparatus as a variation according to the first embodiment.

FIG. 7 is a flowchart of a device manufacturing method according to a second embodiment.

FIG. 8 is a detailed wafer process in FIG. 7.

## BEST MODE FOR CARRYING OUT THE INVENTION

Preferred embodiments of the present invention will now be described in detail in accordance with the accompanying drawings.

### FIRST EMBODIMENT

FIG. 1 is a schematic view of principal part of an exposure according to a first embodiment. This embodiment applies the present invention to a scanning exposure apparatus.

In FIG. 1, 1 denotes an illumination optical system for illuminating a reticle (or a mask) with light from a light source. The light source is an ArF excimer laser (with a wavelength of 193 nm), a KrF

excimer laser (with a wavelength of 248 nm), and $F_2$ laser, and the illumination optical system 1 includes a known optical system etc. (not shown). 3 denotes a refracting or catadioptric or another projection optical system for projecting a circuit pattern on a reticle 2 illuminated by the illumination optical system 1, onto a wafer 5 (substrate) as a second object. 15 denotes a distance measuring laser interferometer for measuring a two-dimensional position on a horizontal plane of each of a reticle stage 12 and a wafer stage 13 via a reference mirror 14. A stage controller 17 controls positioning and synchronizations of the reticle 2 and the wafer 5 based on this measurement value. The wafer stage 13 serves to adjust a position in a longitudinal direction, a rotational angle, and an inclination of a wafer so that the surface of the wafer 5 matches the image surface of the projection optical system 3.

This embodiment uses the local-fill immersion method that forms a liquid film between the final surface of the projection optical system and the wafer so as to shorten the equivalent exposure wavelength, and improve the exposure resolution. Therefore, a liquid supply port 10 and a liquid recovery port 11 are arranged around the final surface of the projection optical system 3, supply liquid and form a liquid film 4 between the final surface of the projection optical

system 3 and the wafer 5. The liquid supply port 10 and liquid recovery port 11 have, for example, a rectangular shape that is long in a lateral direction. This structure achieves a uniform liquid supply to the liquid film and efficient liquid recovery from the liquid film. Alternatively, the liquid supply port 10 and liquid recovery port 11 may be formed to enclose the circumference of the projection optical system 3, or they may include plural nozzles. An interval between the final surface of the projection optical system 3 and the wafer 5 is preferably small enough to stably form the liquid film 4, such as 0.5 mm. A liquid supply unit 6 controls a liquid amount to be supplied between the final surface of the projection optical system 3 and the wafer 5, and includes a degassing system 18 that can have, for example, a well-known membrane module (not shown) and a vacuum pump (not shown). The liquid supply unit 6 is connected to the liquid supply port 10 by a supply pipe 8. A liquid recovery unit 7 controls a liquid amount to be recovered between the final surface of the projection optical system 3 and the wafer 5, and is connected to the liquid recovery port 11 via a recovery pipe 9. An immersion controller 16 sends a control signal to the liquid supply unit 6 and the liquid recovery unit 7, and communicates data with a stage controller 17. Thereby, the immersion controller 16 can adjust the

liquid supply and recovery amounts in accordance with the wafer moving direction and speed, and maintain the liquid film in a predetermined range.

The liquid in the liquid film can be, for example, water. Advantageously, a large amount of water is used in the semiconductor manufacturing process, and the water is compatible with the wafer and photosensitive agent. The liquid in the liquid film may be, for example, so-called functional water that contains a very small amount of additive in water. A variation of a type and concentration of the additive can, for example, control the acidity, and optimize a chemical reaction process of a photosensitive agent. Control over the oxidation and reduction potential can advantageously provide the cleansing power. Alternatively, the liquid in the liquid film may be, fluorine inactive liquid, such as Fomblin (Ausimont Inc.'s product), which has good transmittance to the UV light.

FIG. 2 shows an enlarged liquid film in the apparatus shown in FIG. 1, and a description will be given of its principle with reference to FIG. 2. In FIG. 2, the liquid film 4 fills a space between the final surface of the projection optical system 3 and the wafer 5, and the wafer 5 moves at an average speed V to the left. 4a denotes an exposure area (or projected area), in which the exposure area is

irradiated, and the liquid film 4 is formed and covers the exposure area 4a. When the wafer moves beyond the gas-liquid interface B to the area of the liquid film 4, gas bubbles 19 occur as a result of that the atmosphere is confined in the convex / concave surface, and the gas bubbles 19 move to the exposure area 4a with the wafer. One characteristic of the present invention is that the liquid film part uses the degassed liquid to dissolve the air in the gas bubbles in the liquid and to eliminate the gas bubbles before they reach the exposure area. In other words, this embodiment controls the area of the liquid film so that the following equation is met:

$$L / V > \tau \qquad (2)$$

or the time L / V when the predetermined time of the wafer moves from the gas-liquid interface B to the boundary A between the exposure area and the non-exposure area, is longer than a life $\tau$ of a gas bubble, preventing the gas bubbles 19 from entering the exposure area 4a.

For exposure of the wafer's entire surface, the exposure should be repeated by changing a wafer's moving direction and speed. Even in this case, Equation (2) is effective where L is a distance along the wafer's moving direction, and V is an average speed of the wafer's predetermined part until it reaches the exposure area from the gas-liquid interface.

A description will be given of the life of the gas bubble in the water by assuming that the liquid is water. For simplicity purposes, the gas bubble is sphere that contains only one type of inner gas. In sufficiently degassed water, the concentration $C_\infty$ of dissolved gas distant from the gas bubble is smaller than the saturated concentration $C_S$. Since the gas's molecules diffuse into the water from the surface of the gas bubble, the gas bubble reduces and finally fades away. A period within which the gas bubble vanishes or the life of the bubble is approximated by the following equation (see Epstein and M.S. Plesset, "On the stability of gas bubble in liquid-gas solutions," Journal of Chemical Physics, Volume 18 (1950), pp. 1505-1509, for details):

$$\tau = \frac{\rho d_0^2}{8D(c_s - c_\infty)} \qquad (3)$$

where ρ is the density of the gas in the gas bubble, $d_0$ is an initial diameter of the gas bubble, and D is a diffusion coefficient. Nitrogen and oxygen have the gas densities of 1150 g / $m^3$ and 1310 g / $m^3$, respectively, at 1 atmospheric pressure and 298 K. The diffusion coefficient D of the gas to the water is disclosed, for example, in Incropera and Dewitt, Fundamentals of heat and mass transfer, 5th edition, John Wiley & Sons (2002), p. 927. Nitrogen has 0.26 x $10^{-8}$ $m^2$ / s and oxygen has 0.24 x $10^{-8}$ $m^2$ / s,

respectively. The saturated concentration $C_s$ of gas to the water is calculated from solubility of gas to the water as described, for example, in E. Wilhelm, R. Battino, R. J. Wilcock, "Low-pressure solubility of gases in liquid water," Chemical Reviews Volume 77 (1977), pp. 219-162. Nitrogen and oxygen have the gas densities of 18 ppm and 42 ppm, respectively, at 1 atmospheric pressure and 298 K.

When the atmosphere is the air, the life of the gas bubble is almost dominated by nitrogen that occupies 78 % of volume ratio. FIG. 3 shows a result of the life $\tau$ of the nitrogen bubble in the water calculated by Equation (3) as a function of the diameter $d_0$ of the gas bubble, on the assumption of 1 atmospheric pressure, the room temperature (298 K), and ideal water that completely eliminates the dissolved gas or $C_\infty = 0$. As the wafer moves, a size of the gas bubble is 1 μm at maximum as a result of that the atmosphere is confined in a convex / concave pattern on a surface. When the gas bubble has a diameter of about 1 μm, it is understood from FIG. 3 that the life of the gas bubble is about 3 ms. The diffusion of the gas molecule delays at part that contacts the wafer in the gas bubbles on the wafer surface. The diffusion of the gas molecule also delays when the dissolved air is not completely removed. For these reasons, an actual gas bubble with a diameter of about 1 μm can have a life of

about 10 ms. Therefore, in order to effectively prevent entries of gas bubbles into the exposure area, a range of the liquid film is controlled in accordance with the wafer's moving speed so that L / V becomes at least 10 ms or greater.

A description will now be given of an optimal value of L to a scanning exposure apparatus that synchronously moves the mask and the substrate relative to the projection optical system during exposure. In the scanning exposure apparatus, after a chip area on the wafer is scanned and exposed at a constant speed, the wafer is stepped in a direction approximately orthogonal to the scan direction, and a scan exposure of another chip area is repeated similarly. Since the wafer's moving speed differs between scanning and stepping, the desired value of L also differs. FIG. 4 shows a section of the liquid film and an exposure area, where x is a wafer's moving direction during scanning, y is a wafer's moving direction during stepping, and distances Lx and Ly are distances from the interface of the liquid film to the exposure area in respective directions. The wafer's moving speed is mainly determined by the throughput of the exposure apparatus. The wafer's moving speed is preferably Vx = 1 m / s in the scanning direction. If it is assumed that the life of the gas bubble is $\tau$ = 10 ms, Lx is preferably 10 mm or greater from Equation (2). Taking the difficulties

of precise control over the liquid film area into consideration, it is more preferable that Lx is 20 mm or greater to maintain the double safety. The wafer's moving speed is preferably Vy = about 0.5 m / s in the stepping direction, about half the speed in the scanning direction, when the acceleration and deceleration are considered. Therefore, Ly is preferably 5 mm or greater from Equation (2), and it is more preferable that Ly is 10 mm or greater to maintain the double safety. On the other hand, as L becomes larger, the apparatus becomes large and control over the liquid film becomes difficult disadvantageously. In addition, scanning and stepping distances at one time are almost determined by a size of the mask image transferred onto the wafer, and usually about 50 mm in the scanning direction and about 30 mm in the stepping direction. The effect of eliminating gas bubbles does not improve even when values of Lx and Ly are made much greater than these moving directions. For these reasons, it is preferable that Lx is made between 10 mm and 100 mm and Ly is made between 20 mm and 70 mm. More preferably, Lx is made between 20 mm and 70 mm and Ly is made between 10 mm and 50 mm.

A description will now be given of influence of the concentration of dissolved gas. As understood from Equation (3), the life of a gas bubble is in inverse proportion to a difference between the concentration $C_\infty$

of actually dissolved gas and the saturated concentration $C_s$ of the gas. In order to prevent the entries of gas bubbles into the exposure area, the life of gas bubble is preferably as short as possible. Therefore, the concentration of gas dissolved in the water is made sufficiently smaller than the saturated concentration. FIG. 5 shows the normalized life $\tau / \tau_0$ of a gas bubble, as a result calculated by Equation (3), using as a function of $C_s / C_\infty$ as a normalized concentration of dissolved gas, where $\tau_0$ is the life when $C_\infty = 0$. When normalized concentration $C_s / C_\infty$ is 0.2 or smaller, the life of a gas bubble is close to that where the degassing is perfect. On the other hand, when normalized concentration $C_s / C_\infty$ becomes 0.5 or greater, the life of a gas bubble drastically increases. As a result of this, the concentration of gas dissolved in the water is preferably 50 % or smaller of the saturated concentration, and more preferably 20 % or smaller of the saturated concentration.

When the atmosphere is air, the nitrogen concentration that occupies about 78 % and the oxygen concentration that occupies about 21 % with respect to the partial pressure in the air are important. When it is assumed that the partial pressure of nitrogen is 0.78 atmospheric pressure and that of oxygen is 0.21 atmospheric pressure, the saturated concentrations of nitrogen and oxygen to water are respectively about 14

ppm and 9 ppm at the room temperature (or 298 K). Therefore, it is preferable to maintain the concentrations of nitrogen and oxygen dissolved in the water within 7 ppm and 4.5 ppm, respectively, more preferably, within 2.8 ppm and 1.8 ppm, respectively.

As apparent from the above description, it is important that the liquid of the liquid film has been degassed in the inventive exposure apparatus. However, the exposure apparatus can omit the degassing system if an external apparatus has a degassing function for liquid to be supplied to the exposure apparatus. For example, the water purifier used for the semiconductor manufacturing process usually has a degassing function, which can reduce the concentrations of nitrogen and oxygen down to 1 / 1000 or smaller times the saturated concentration in the air.

FIG. 6 is a schematic view of a principal part of a variation of this instant embodiment. This variation differs from the exposure apparatus of the first embodiment in FIG. 1 in that there is no degassing system 18. The remaining structure is the same.

According to the above embodiment, for example, fine gas bubbles generated on the substrate surface as the substrate moves are prevented from entering the exposure area.

Gas bubbles can be generated at part other than the substrate surface, for example, at the top part of

the liquid supply port 10, be attracted by the substrate, and move to the exposure area. Even in this case, the above embodiment can prevent gas bubbles from entering the exposure area, since the top of the liquid supply port 10 is located at approximately the same position as that of the gas-liquid interface B of the liquid film 4.

Thus, this embodiment enables the exposure apparatus of a local fill immersion method to prevent entries of gas bubbles into the exposure area.

**SECOND EMBODIMENT**

A description will now be given of an embodiment of a device manufacturing method using the above exposure apparatus.

FIG. 7 is a flowchart for explaining a fabrication of devices (*i.e.*, semiconductor chips such as IC and LSI, liquid crystal panels, and CCDs). Step 1 (circuit design) designs a device circuit. Step 2 (reticle production) forms a reticle having the designed circuit pattern. Step 3 (wafer process) forms a circuit pattern on a wafer using the lithography. Step 4 (assembly process) separates the individual circuit patterns from the wafer and produces a device through wiring and packaging.

FIG. 8 is a detailed flowchart of the wafer process. Step 11 (coating) forms various coatings

using the thermal oxidation, chemical vapor deposition, and physical gas phase growth. Step 12 (resist application) applies the resist and antireflective coating onto the wafer. Step 13 (exposure) uses the above exposure apparatus to expose a mask pattern onto the wafer. Step 14 (development) develops the wafer. Step 15 (etching) etches the wafer. Step 16 (ion implantation) implants ions into the wafer. Step 17 (resist release) removes the resist from the wafer. These steps are repeated, and multi-layer circuit patterns are formed on the wafer. The fabrication method of the instant embodiment may manufacture higher quality devices than the prior art.

As many apparently widely different embodiments of the present invention can be made without departing from the spirit and scope thereof, it is to be understood that the invention is not limited to the specific embodiments thereof except as defined in the claims.

## INDUSTRIAL APPLICABLITY

The above description explained the case where the present invention is applied to an exposure process that uses a wafer as a processed material. However, the applicability of the present invention is not limited to a wafer process. It can be generally applied to

pattern-forming exposure processes that include, for example, an exposure process in reticle manufacturing where an electronically-controlled spatial light modulator may be used as a mask.

## CLAIMS

1. An exposure apparatus comprising:

a projection optical system for projecting a pattern on a mask onto a substrate;

a stage for retaining and moving the substrate; and

a liquid film forming means for forming a liquid film between a final surface of the projection optical system and the substrate,

wherein $L / V > \tau$ is met where $\tau$ is a life of a gas bubble generated in the liquid film, V is a moving speed of the substrate, and L is a distance from an interface of the liquid film to an exposure area along a moving direction of the substrate.

2. A scanning exposure apparatus comprising:

a projection optical system for projecting a pattern on a mask onto a substrate;

a stage for retaining and moving the substrate; and

a liquid film forming means for forming a liquid film between a final surface of the projection optical system and the substrate,

wherein a distance is between 10 mm and 100 mm from an interface of the liquid film to an exposure area along a moving direction of the substrate, and a

distance is between 5 mm and 80 mm from an interface of the liquid film to an exposure area along a moving direction orthogonal a scan direction of the substrate.

3. A scanning exposure apparatus according to claim 2, wherein the distance is between 20 mm and 70 mm from the interface of the liquid film to the exposure area along the moving direction of the substrate, and the distance is between 10 mm and 50 mm from the interface of the liquid film to the exposure area along the moving direction orthogonal the scan direction of the substrate.

4. An exposure apparatus according to claim 1, wherein liquid in the liquid film has an average concentration of dissolved nitrogen of 7 ppm or smaller, and an average concentration of dissolved oxygen of 4.5 ppm or smaller.

5. An exposure apparatus according to claim 1, wherein liquid in the liquid film has an average concentration of dissolved nitrogen of 2.8 ppm or smaller, and an average concentration of dissolved oxygen of 1.8 ppm or smaller.

6. An exposure apparatus according to claim 1, wherein said liquid film forming means includes a

liquid feed port for supplying liquid between the final surface of the projection optical system and the substrate, and a liquid recovery port for recovering the liquid between the final surface of the projection optical system and the substrate.

7. An exposure apparatus according to claim 1, wherein the liquid film contains deaerated liquid.

8. A device manufacturing method comprising the steps of:

exposing a substrate using an exposure apparatus according to any one of claims 1 to 7; and

developing the object exposed.

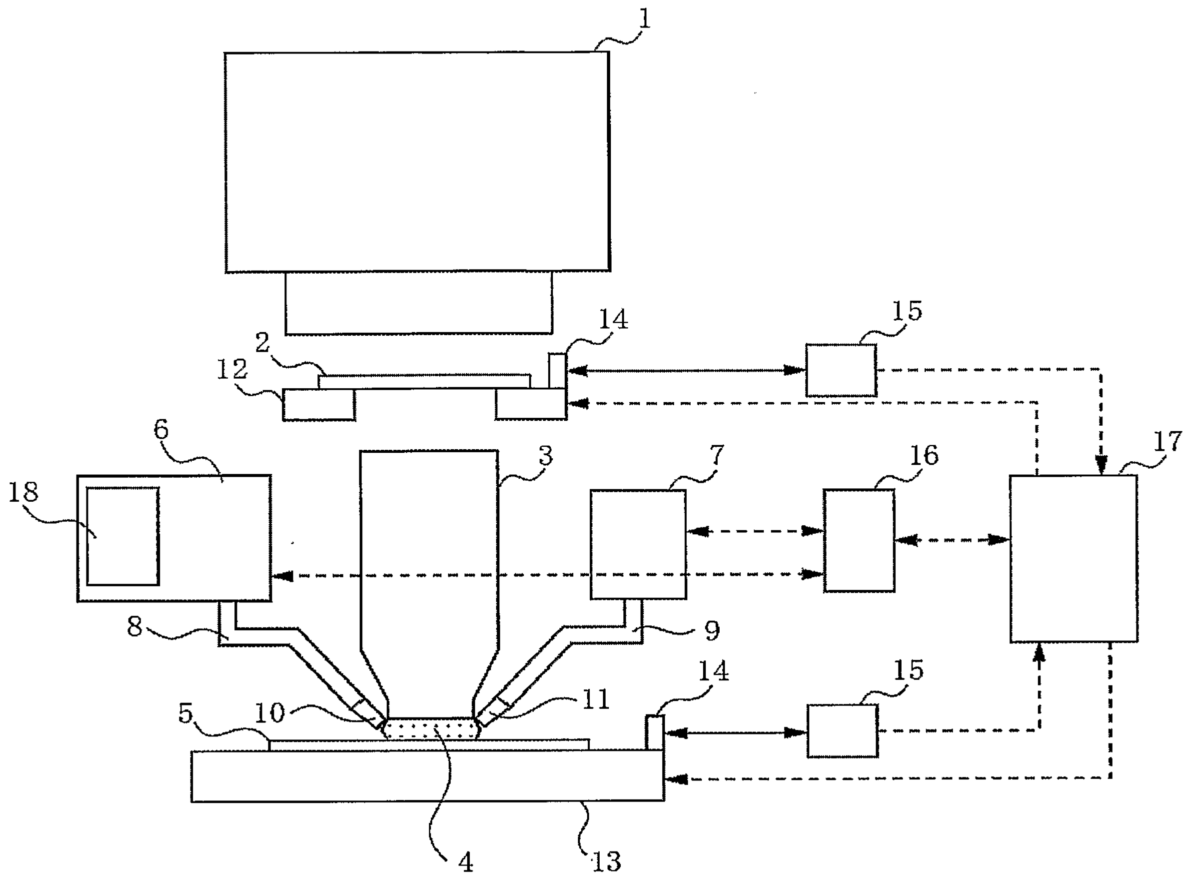


FIG. 1

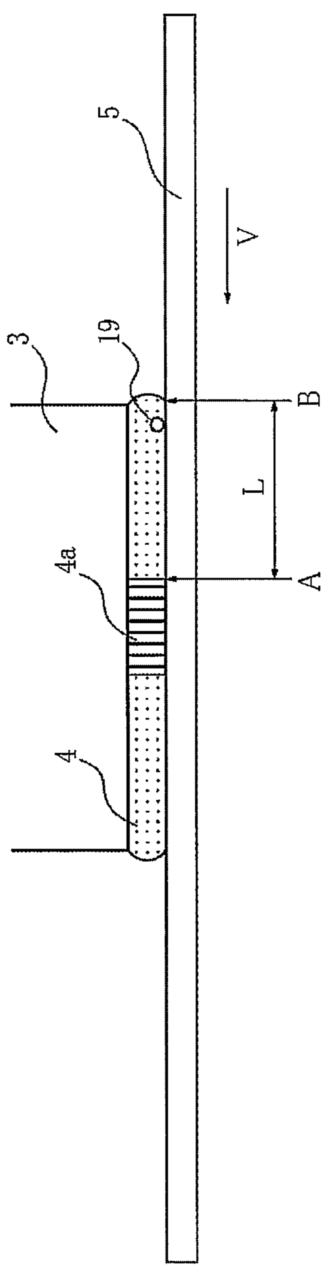


FIG. 2

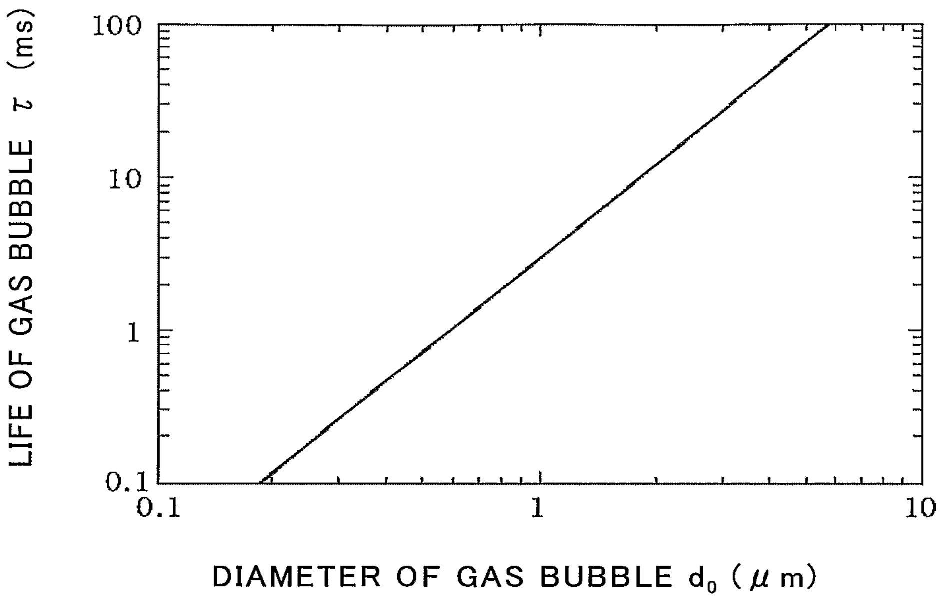
LIFE OF GAS BUBBLE τ (ms)
100
10
1
0.1
0.1
1
10
DIAMETER OF GAS BUBBLE d0 (μm)

FIG. 3

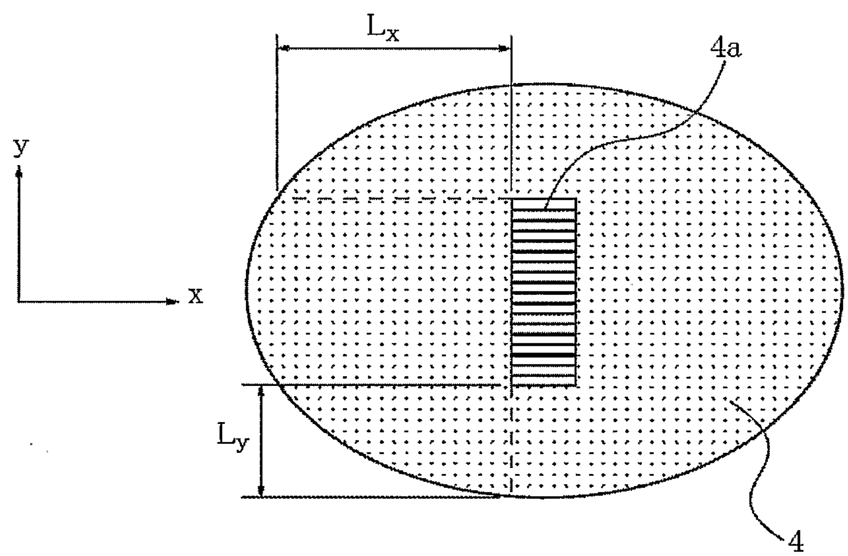


FIG. 4

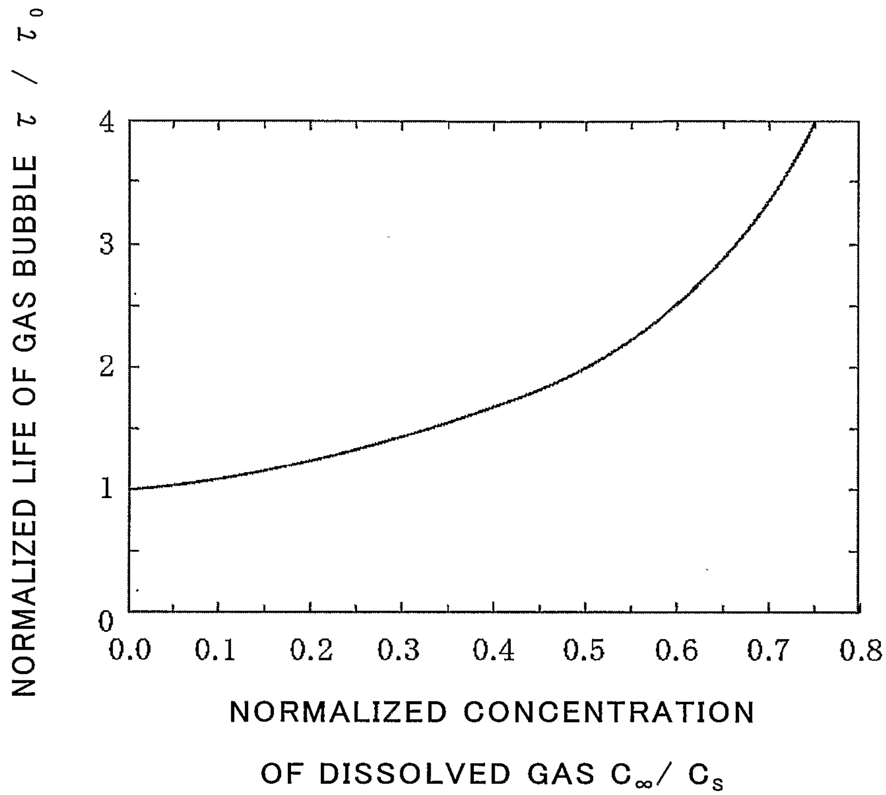
NORMALIZED LIFE OF GAS BUBBLE $\tau / \tau_0$
0
1
2
3
4
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8
NORMALIZED CONCENTRATION
OF DISSOLVED GAS $C_\infty / C_S$

FIG. 5

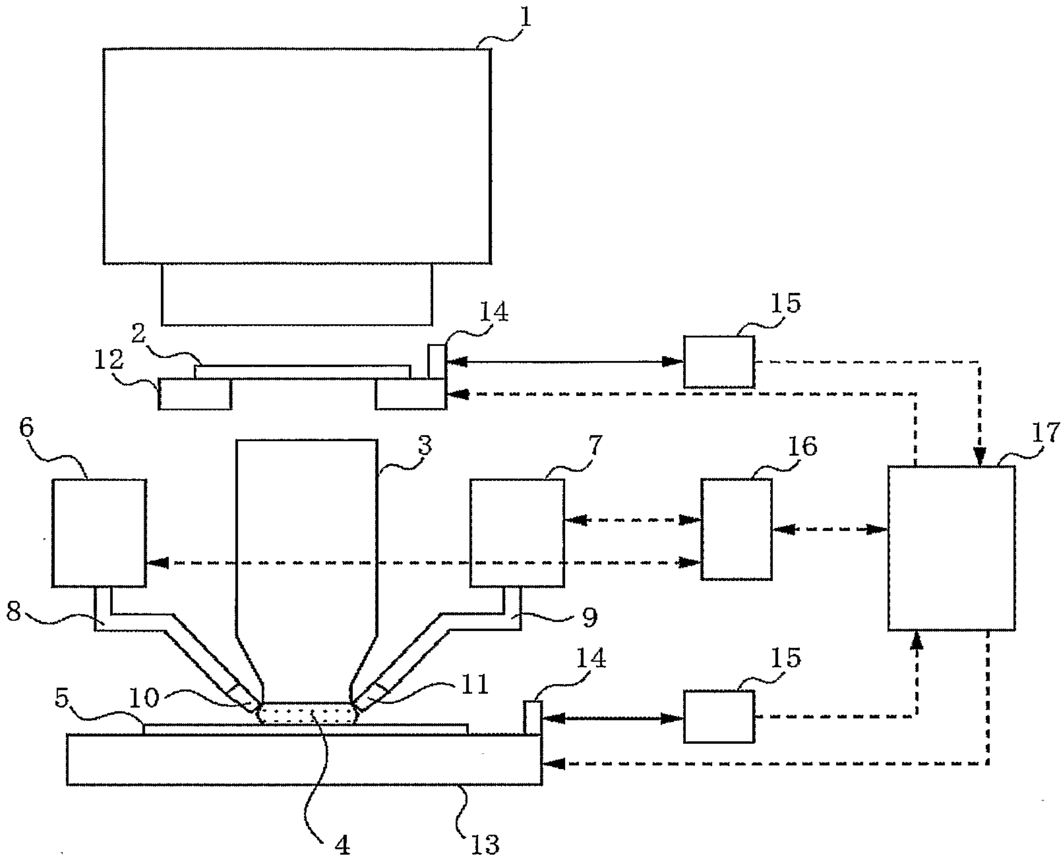


FIG. 6

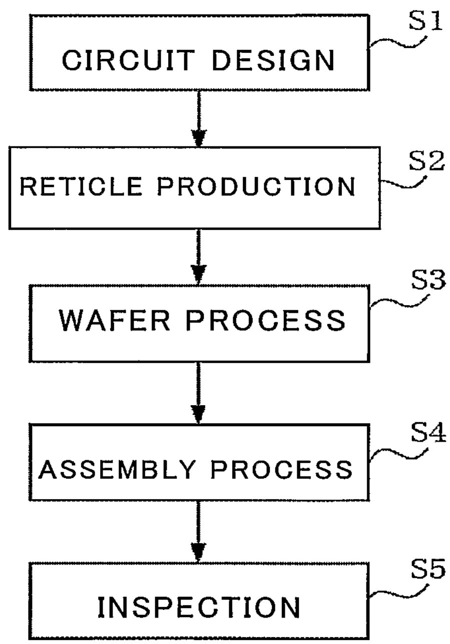
CIRCUIT DESIGN
S1
RETICLE PRODUCTION
S2
WAFER PROCESS
S3
ASSEMBLY PROCESS
S4
INSPECTION
S5

FIG. 7

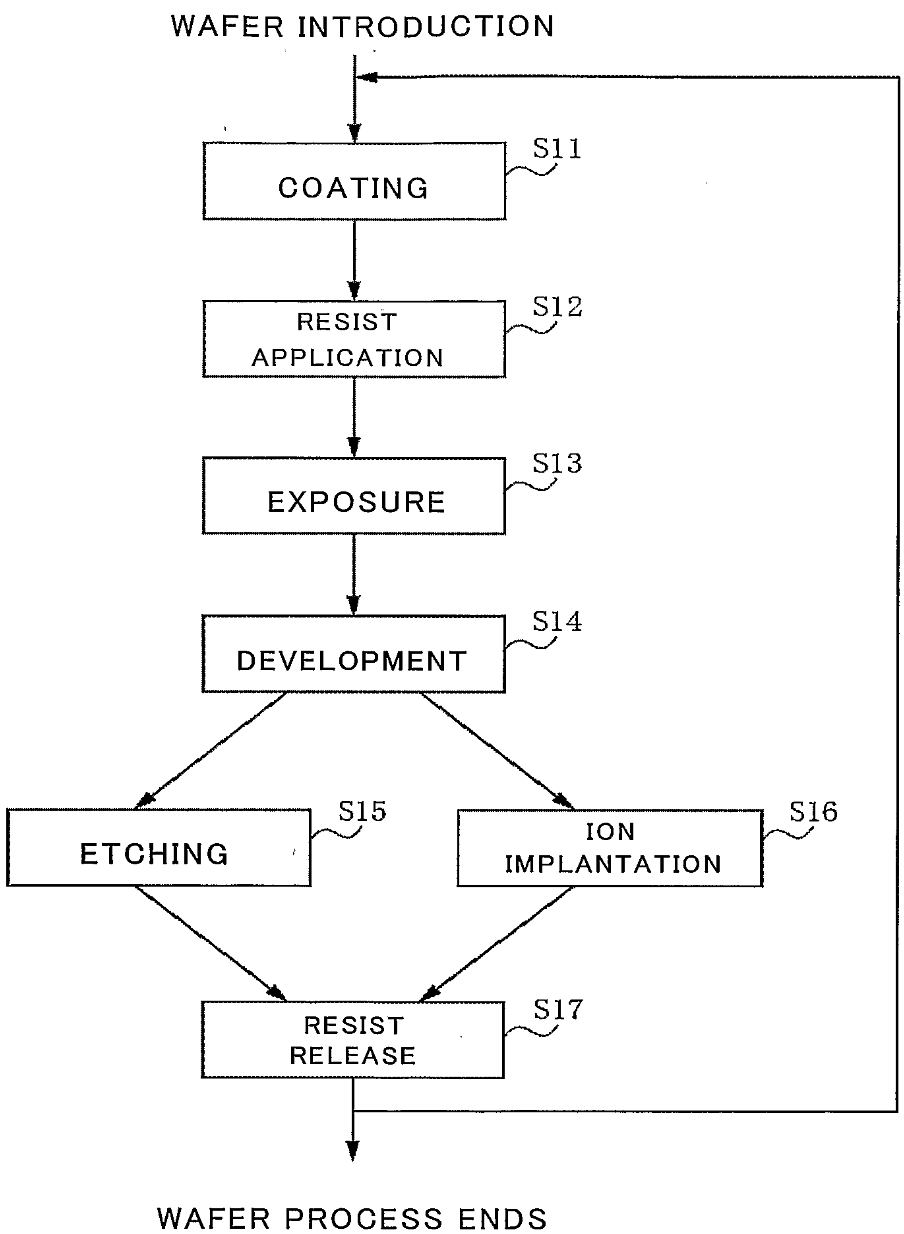
WAFER INTRODUCTION
COATING
S11
RESIST APPLICATION
S12
EXPOSURE
S13
DEVELOPMENT
S14
ETCHING
S15
ION IMPLANTATION
S16
RESIST RELEASE
S17
WAFER PROCESS ENDS

FIG. 8

International application No.
PCT/JP2004/017122

A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl⁷ H01L21/027, G03F7/20

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int.Cl⁷ H01L21/027, G03F7/20

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Japanese Utility Model Gazette 1922-1996, Japanese Publication of Unexamined Utility Model Applications 1971-2005, Japanese Registered Utility Model Gazette 1994-2005, Japanese Gazette Containing the Utility Model 1996-2005

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X<br>Y | WO 99/49504 A1 (NIKON Corp.), 1999.09.30, the whole document, & AU 9927479 A | 1-3,6,8<br>4,5,7 |
| A | JP 2000-252206 A (NIKON Corp.), 2000.09.14, the whole document (especially [0030]-[0033] and Fig.3), (Family:None) | 2,3 |
| A | JP 2003-532282 A (ASML US. Inc.), 2003.10.28, the whole document (especially [0009],[0051]-[0053]), & WO 2001/082000 A1 | 2,3 |

☑ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
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- "E" earlier application or patent but published on or after the international filing date
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- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed
- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- "&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 17.02.2005 | 08. 3. 2005 |

| Name and mailing address of the ISA/JP | Authorized officer |
|---|---|
| Japan Patent Office<br>3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan | 2M 3154<br>HIDEKI SATO<br>Telephone No. +81-3-3581-1101 Ext. 3274 |

**INTERNATIONAL SEARCH REPORT**

International application No.
PCT/JP2004/017122

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| Y | JP 06-168866 A (CANON KK.), 1994.06.14, the whole document (especially [0026]), & EP 605103 B1 & US 5610683 A1 | 4,5,7 |
| A | JP 59-019912 A (HITACHI Ltd.), 1984.02.01, the whole document, (Family:None) | 1-8 |
| A | JP 06-124873 A (CANON KK.), 1994.05.06, the whole document, (Family:None) | 1-8 |
| EX | JP 2004-343114 A (ASML NETHERLANDS B.V.), 2004.12.02, the whole document (especially [0084]), & US 2005/0007569 A1 (see [0099]) | 1-3,6,8 |